A Panchromatic
Gamma Ray Burst
MIDEX Mission

Mission Operations Plan

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Swift Ground Segment

Omitron Inc.

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TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 PURPOSE 1
1.2 SCOPE 1
1.3 APPLICABLE DOCUMENTS 1

2.0 MISSION DESCRIPTION 3

2.1 SPACECRAFT 4
2.2 INSTRUMENTS 5
2.3 GROUND SYSTEM 6
2.4 LAUNCH SEGMENT 6

3.0 OPERATIONS MANAGEMENT 8

3.1 SWIFT PROJECT ORGANIZATION 8
3.2 SWIFT OPERATIONS ORGANIZATION 9
3.3 MISSION OPERATIONS WORKING GROUP 10

4.0 GROUND SYSTEM OVERVIEW 12

4.1 MALINDI GROUND STATION 13
4.2 TDRSS 13
4.3 COMMERCIAL BACKUP GROUND STATION 13
4.4 GROUND COMMUNICATIONS NETWORK 13
4.5 SWIFT MISSION OPERATIONS CENTER (MOC) 14
4.6 SWIFT DATA CENTER (SDC) 14
4.7 SWIFT SCIENCE CENTER (SSC) 15
4.8 GAMMA-RAY COORDINATES NETWORK (GCN) 15
4.9 HEASARC/DATA ARCHIVAL 15
4.10 INTERNATIONAL DATA CENTERS 15
4.11 EDUCATION AND PUBLIC OUTREACH (E/PO) 16
4.12 SPACECRAFT AND INSTRUMENT SUSTAINING ENGINEERING FACILITIES 16

5.0 PRE-LAUNCH OPERATIONS PREPARATION 17

5.1 TRAINING 17
5.2 OPERATIONS PRODUCTS DEVELOPMENT 17
5.3 OBSERVATORY I&T 19
5.4 RF COMPATIBILITY TESTING 19
5.5 SPACECRAFT INTERFACE TESTING 19
5.6 MISSION READINESS TESTING 19
5.7 END-TO-END (ETE) TESTING 19
5.8 MISSION SIMULATIONS 20

6.0 LAUNCH AND EARLY ORBIT (L&EO) OPERATIONS 21

7.0 NORMAL ON-ORBIT MISSION OPERATIONS 23

7.1 OVERVIEW OF NORMAL ON-ORBIT OPERATIONS ..... 23~~23~~
7.2 MISSION PLANNING AND SCHEDULING ..... 25~~25~~
7.3 ROUTINE OPERATIONS ACTIVITIES ..... 28~~29~~
7.3.1 Commanding ..... *28~~29~~*
7.3.2 Spacecraft & Instrument Monitoring ..... *29~~30~~*
7.3.3 Recorder and Memory Management ..... *29~~30~~*
7.3.4 Spacecraft Clock Management ..... *32~~33~~*
7.3.5 Ephemeris Updates ..... *32~~33~~*
7.3.6 ToO Requests ..... *33~~34~~*
7.4 OFFLINE ACTIVITIES ..... 33~~34~~
7.4.1 Data Processing and Delivery ..... *33~~34~~*
7.4.2 Trending and Analysis ..... *33~~34~~*
7.4.3 Data Accountability ..... *34~~35~~*
7.5 MAINTENANCE FUNCTIONS AND SUSTAINING ENGINEERING ..... 36~~37~~
7.6 CONFIGURATION MANAGEMENT ..... 37~~38~~
7.7 ANOMALY RESOLUTION ..... 38~~39~~
7.8 MISSION STATUS REPORTING ..... 38~~39~~

8.0 STAFFING PLAN ..... 39~~40~~

8.1 LAUNCH AND 30-DAY CHECKOUT ..... 39~~40~~
8.2 VERIFICATION/INSTRUMENT CHECKOUT ..... 42~~43~~
8.3 NORMAL OPERATIONS ..... 43~~44~~

APPENDIX A – ACRONYM LIST ..... 44~~45~~

FIGURES

Figure 2-1 Swift Observatory ..... 4~~4~~
Figure 3-1 GNEST Team Organization ..... 8~~8~~
Figure 3-2: Swift Mission Operations Organization ..... 10~~10~~
Figure 4-1: Swift Mission Architecture ..... 12~~12~~
Figure 7-1: Mission Planning & Scheduling Operational Flow ..... 27~~27~~
Figure 7-2: Mission Planning – "A Week in the Life of Swift" ..... 28~~28~~
Figure 7-3: Real-Time Operational Flow ..... 31~~32~~
Figure 7-4: Offline Operational Flow ..... 35~~36~~

TABLES

Table 7-1 MOC Products Posted to the Web ..... 24~~24~~
Table 8-1. MOC Staffing Plan for L&EO/30-Day Checkout ..... 40~~41~~

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a baseline plan for the on-orbit operations of the Swift mission. The activities and tasks to be performed by the Flight Operations Team (FOT) are described for each of the pre-launch, launch and early-orbit, and normal operations phases of the mission.

1.2 SCOPE

The scope of the Mission Operations Plan includes the flight operations-related plans for the implementation of the Swift mission, including:

- descriptions of the space and ground segments
- operations organization, management and staffing
- flight operations activities including mission planning, commanding, health and safety monitoring, flight dynamics support, pass execution, anomaly resolution and sustaining engineering
- training of FOT members

The MOP provides an overview for space and ground segment operations with particular focus on flight operations. This plan provides the basis for the development of detailed flight and ground system operating procedures, which are documented separately. In general, information contained in other project documents are not replicated in this document, but rather referenced to the appropriate document. The reader is encouraged to become familiar with the operations concepts and requirements for the mission.

1.3 APPLICABLE DOCUMENTS

The following documents were referenced during the development of this document. The reader is encouraged to use present and future versions of these documents for further research. Most of the documents are available on the Swift Project and Ground Network for Swift (GNEST) web sites.

- *Swift Science Requirements Document*, GSFC-661-Swift-SRD, 410.4-SPEC-0005D, Rev. E, February, 2002.
- *Requirements of the Ground System for the Swift Mission*, 410.4-SPEC-0007, Revision 2.0, May, 2002.
- *Swift Mission Operations Concept Document*, Swift-OMI-001, Baseline Version 1.1, July 2001.
- *Mission Operations Agreement: Swift Mission Operations Roles & Responsibilities,* August 2001.
- *MOC Development Plan*, Swift-OMI-002, Baseline Version 1.0, January 2002.
- *MOC Design Specification Document*, Swift-OMI-003, Version 2.0, January 31, 2003.
- *Swift MOC Functional and Performance Requirements,* Swift-OMI-004, Version 1.1, April 2002.

- *MOC Verification Plan*, Swift-OMI-009, Baseline Version 1.1, October 2002.
- *MOC Build Plan,* Swift-OMI-014, Version 1.4, February, 2003.
- *Swift ITOS Database Format Control Document,* Swift-OMI-013, Version 1.2, May 30, 2002.
- *Swift Ground System Test Plan,* 410.4-PLAN-0028, Version 1.1, June 2002.
- *Spacecraft To Mission Operations Center (MOC) Interface Control Document,* 1143-EI-M022927, Rev. A, June, 2002.
- *Space Vehicle Handbook,* 1143-EU-MO28760, Preliminary, April 18, 2002.
- *Swift On-Orbit Handbook,* 1143-EU-MO28768, Preliminary, April 18, 2002.
- *Swift to Delta II Launch System ICD,* MDC-01H0041, Draft, May 31, 2002.
- *MOC Training & Certification Plan,* Swift-OMI-011, Preliminary, October 31, 2002.
- *Swift Mission Operations Readiness Plan,* TBS.
- *TBS: Instrument Description Manuals*
- *Swift Flight Procedures Document*

2.0 MISSION DESCRIPTION

Swift is a Medium-class Explorers (MIDEX) mission that will greatly expand our knowledge of Gamma-Ray Bursts (GRBs), their origin and characteristics. The Swift mission involves the 3-year operation of the Swift spacecraft and instruments to perform multiwavelength observations of the afterglow characteristics from GRBs. Swift plans a comprehensive study of ~1000 bursts. Swift has a panchromatic approach utilizing three instruments, including the Burst Alert Telescope (BAT) and two Narrow Field Instruments (NFI): the X-Ray Telescope (XRT), and Ultra-Violet/Optical Telescope (UVOT). The mission combines the capabilities and strengths of the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) and its university and industry partners. Swift has a multi-national approach. The United Kingdom (UK) and Italy are making major contributions of flight hardware and data analysis facilities. The Italian Space Agency (ASI) is contributing the Malindi Ground Station in Kenya for spacecraft telemetry downlink and command uplink. The Swift science team has representatives from the United States, the UK, Italy, Germany, Japan and France. Dr. Neil Gehrels of NASA/GSFC is the Principal Investigator (PI).

Spectrum Astro is building the spacecraft bus and leading the Observatory Integration and Test (I&T). NASA/GSFC has program management responsibility and is developing the BAT instrument with flight software from the Los Alamos National Laboratory (LANL). The Pennsylvania State University (PSU) has responsibility for the NFIs and Mission Operations. PSU's partner Omitron is developing the ground system and providing flight operations. University of Leicester (UL, UK) is contributing the Charge Coupled Device (CCD) camera and telescope integration facilities for the XRT. The Brera Observatory (OAB, Italy) is contributing the flight spare mirror from the JET-X instrument on Spectrum – X for the XRT. The Mullard Space Science Laboratory (MSSL) of University College London (UCL) is contributing the detectors, mirrors, and other major components of the UVOT, using a design which is largely a copy of the Optical Monitor on the X-Ray Multi-Mirror (XMM) satellite. The Italian Space Agency (ASI) is contributing the Malindi Ground Station in Kenya for spacecraft telemetry downlink and command uplink.

The Swift mission phases include pre-launch, launch and early orbit (L&EO), verification, and normal operations. The pre-launch phase is comprised of spacecraft bus and instrument development, I&T, ground system development and establishment of communications links, ground system testing, operations simulations, and launch site processing. The L&EO phase commences with launch and includes the on-orbit commissioning and checkout, which is expected to last for 30 days. Following successful checkout, the verification phase begins for instrument checkout and calibration, and verification of science data. Once the instruments have been verified, the mission transitions to the normal operations phase.

The Swift spacecraft will be launched on a Boeing Delta II 7320 vehicle from the Cape Canaveral Air Force Station (CCAFS), Florida. A launch date of September 30, 2003 is currently scheduled. Swift will then settle into an orbit at an altitude of 600 km and an inclination of 19 degrees, orbiting the Earth once every 96 minutes. Following the 30-day checkout period, the nominal 35-month science mission will commence. Figure 2-1 depicts the Swift Observatory.

For additional information on the science objectives and mission concepts reference the *Swift Mission Operations Concept Document* and the *Swift Science Requirements Document*.

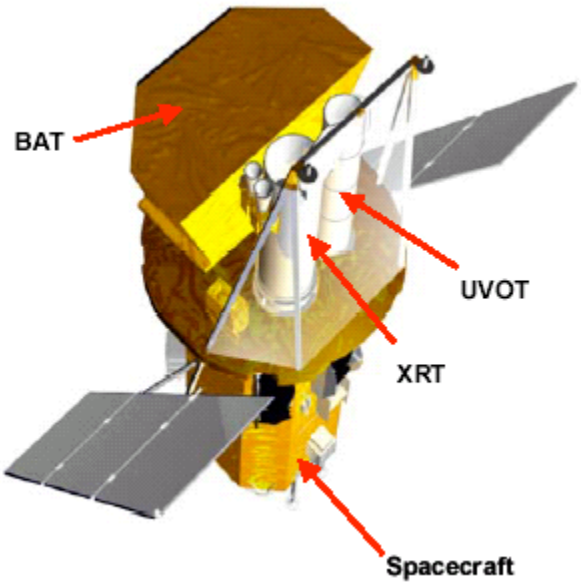

Figure 2-1 Swift Observatory

2.1 SPACECRAFT

The Swift spacecraft bus is a three-axis stabilized, solar-powered structure that provides the communications interfaces between the instruments and the ground, rapidly and accurately orients the instruments to the observation targets, and provides power, timing information and data storage for the instruments. The Swift observatory operates in a circular 600 km altitude orbit, and normally observes a set of pre-planned targets uploaded by the FOT in the MOC via the Malindi Ground Station. Once a day, on average, during the course of the pre-planned observations the BAT instrument will detect a new GRB within its field of view. Swift then transmits a burst alert message to the ground via the TDRSS system. If the figure of merit (FoM) software determines that observation of the newly discovered burst should take priority over the current observations then it sends a slew request to the spacecraft bus. The Predict Ahead Planner Algorithm (PAPA) in the ACS FSW determines if the target can be observed without violating any pointing constraints. The pointing constraints include the sun, the Earth limb, the moon, and the ram (velocity) direction. PAPA verifies that the burst location is outside the pointing constraints and then calculates the shortest path to the target and begins slewing. When the slew is complete the ACS FSW notifies the instruments that the XRT and UVOT can begin observing the burst. All instrument science data is stored on-board Swift in the SSR for playback during a contact via the Malindi Ground Station.

Reference the *Space Vehicle Handbook (SVH)* for detailed descriptions of the spacecraft subsystems and the *On-Orbit Handbook (OOH)* for descriptions of the spacecraft operations procedures, constraints and restrictions.

Spectrum Astro is developing the spacecraft and leading Observatory I&T (integration of spacecraft and instruments). Spectrum is delivering the spacecraft to NASA on-orbit, where delivery of the spacecraft to NASA is predicated on validation of the spacecraft functionality and the bus-to-instruments interfaces. Spectrum Astro also provides sustaining engineering support during the normal operations phase.

2.2 INSTRUMENTS

The Swift instrument compliment is comprised of 3 co-aligned instruments: the BAT, XRT, and UVOT. The XRT and UVOT produce arc-second positions and multi-wavelength light curves for GRB afterglows. Broadband afterglow spectroscopy will produce red shifts for the majority of GRBs. BAT is a wide Field-Of-View (FOV) coded-aperture imager that will produce arc-minute GRB positions onboard within 10 seconds.

The BAT is a wide-field coded aperture instrument with 5200 cm2 of CdZnTe detectors. The mask size is the largest that can fit in the 3 m Delta fairing and gives a 2 steradian half-coded field of view. When the BAT detects a count rate increase, it produces an image by convolving the detector array outputs with the mask pattern stored in the Image Processor Electronics (IPE). If a point source is found an alert is sent to the ground via TDRSS and the FoM software determines if the newly detected burst merits observation with the narrow field of view instruments. BAT also generates light curves and spectra of the GRB.

The FoM is the onboard instrument FSW used to coordinate the observations of preplanned and autonomous targets, which is hosted within the BAT instrument processor. The BAT FSW continuously processes event data from the BAT detectors in order to detect GRBs. Following burst detection, the BAT FSW will determine the position of the burst, and the FoM FSW will determine whether the newly detected burst is of higher merit than the current preplanned observation. Given the desire to slew to the new burst, the FoM will request the spacecraft slew to the new position. The FoM coordinates all observations in order to achieve the overall science goals.

The XRT is a highly sensitive, autonomous X-ray CCD imaging spectrometer. A nested grazing incidence Wolter I telescope unit focuses X-rays onto the focal plane camera, which contains a single Marconi Applied Technologies CCD-22 detector. Swift will use the existing JET-X FM3 mirror set (the flight spares) which have a 3.5 m focal length. The XRT can operate in three modes. Imaging Mode accommodates multi-photon superposition during initial burst observation and gives photometry and source location for sources as bright as 26 Crab. Photon-Counting Mode is a single photon counting mode for spectra and photometry with full CCD spectral resolution and maximum source sensitivity. Timing Mode is used to measure source spectra and temporal variability with resolution of <10 msec.

The UVOT is a 30 cm modified Ritchey-Chrétien UV/optical telescope that provides simultaneous UV/optical coverage over a 17’ x 17’ field-of-view, and will reach a 24th magnitude limit for a 1000 second observation. The UVOT is fully redundant excluding the optics. An 11-position filter wheel allows low-resolution grism spectra of bright GRBs,

magnification, and broadband UV/visible photometry. Photons register on a Micro-Channel Plate Intensified CCD. The Digital Electronics Modules (DEMs) detect photon events in the CCD images, and power supplies that convert the spacecraft 28V service to the various services needed by the telescope. A DEM is responsible for high-level command and control of the UVOT and consists of the Instrument Control Unit (ICU), Data Processing Unit (DPU), and power supplies all contained in a common enclosure. The ICU is a general-purpose computer built around a 31750 microprocessor that carries the DEM's Instrument Control Bus interface with the Telescope Module (TM) electronics. The ICU hosts the software responsible for executing UVOT commands received from the spacecraft, for monitoring and controlling the operation of the telescope, and for generating housekeeping telemetry. The DPU is a general-purpose computer built around a RAD6000 microprocessor and carries the DEM's data capture interface with the TM electronics.

Reference the *Instrument Description Manuals* for additional information.

The Instrument Teams include the BAT team located at GSFC, and the XRT and UVOT teams located at PSU, with additional support from teams at the University of Leicester, the Mullard Space Science Laboratory, the Brera Observatory, Southwest Research Institute, and LANL. The Instrument Teams maintain facilities for the maintenance of instrument flight software and for the analysis of instrument performance. These sustaining engineering facilities receive engineering data from the MOC, and provide flight software loads and commands to the MOC for uplink to the spacecraft. The Instrument Teams also provide participants as members of the SOT within the MOC to perform science planning and assessment of science data and instrument performance.

2.3 GROUND SYSTEM

The Swift Ground System is comprised of the Mission Operations Center (MOC) located at Pennsylvania State University (PSU) in State College, PA, the Swift Data Center (SDC) and Swift Science Center (SSC) located at GSFC, the Malindi Ground Station in Kenya, Africa, the Space Network (SN)/Tracking and Data Relay Satellite System (TDRSS), the Universal Space Network (USN) Hawaii ground station, and the associated communications links. See Section 4.0 for additional information.

Mission operations will primarily be supported from the MOC facility at PSU. PSU personnel will provide lead flight operations support, using Omitron as the Flight Operations Team (FOT) contractor. PSU will also provide lead science operations support for the NFI's (UVOT and XRT), as well as support for the BAT instrument. This group is referred to as the Science Operations Team (SOT). Lead operations support for BAT will be provided by the BAT instrument team at GSFC, which will interact directly with the SOT at PSU for BAT science operations planning.

2.4 LAUNCH SEGMENT

The Swift observatory will be launched aboard a Boeing Delta II 7320-10 expendable launch vehicle (ELV) from the Cape Canaveral Air Force Station. Kennedy Space Center (KSC) will

provide launch processing and control through orbit injection. The Flight Dynamics Facility (FDF) at GSFC will provide launch vehicle tracking support and provide the orbit insertion vector to the MOC after separation. Reference the *Swift to Delta II Launch System ICD* and the *OOH* for additional information.

3.0 OPERATIONS MANAGEMENT

3.1 SWIFT PROJECT ORGANIZATION

The Swift Project is managed by the Goddard Space Flight Center (GSFC), Greenbelt, MD. The Swift Project Office has overall project management responsibility to develop, deliver and operate the Swift mission. The Swift Principal Investigator (PI) is Dr. Neil Gehrels of GSFC, who has overall responsibility for the accomplishment of the mission and meeting the science objectives. The Swift Project Office is headed by Joe Dezio, Project Manager, and includes spacecraft and instrument management, systems engineering management, and ground system management. The ground system, or Ground NEtwork for SwifT (GNEST), is managed by Frank Marshall, GSFC Code 662. The GNEST organization is depicted in Figure 3-1. Refer to the *GNEST Project Management Plan* for additional information. Details of the roles and responsibilities of the organizations involved in operations are described in the *Mission Operations Agreement: Swift Mission Operations Roles & Responsibilities* document.

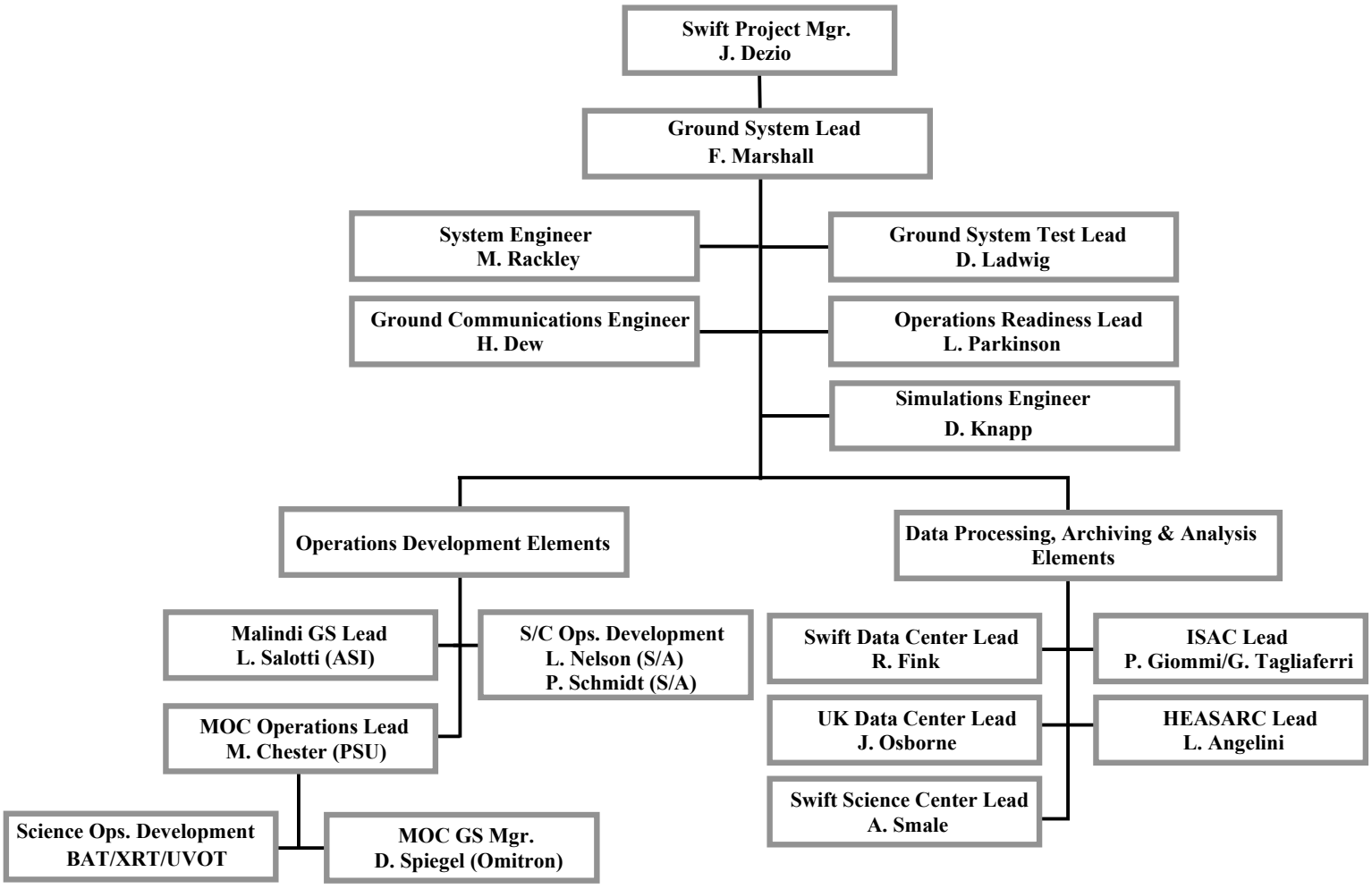

Figure 3-1 GNEST Team Organization

3.2 SWIFT OPERATIONS ORGANIZATION

The Swift mission operations team (MOT) is composed of all elements involved in the operation of the observatory, as shown in Figure 3-2, including:

- Flight Operations Team (FOT) – responsible for flight operations in the MOC (Omitron)
- Science Operations Team (SOT) – responsible for science planning and analysis in the MOC (PSU)
- Swift Project Office (NASA) – responsible for overall project management and accomplishment of the science objectives of the mission, institutional support
- Spacecraft Team (Spectrum Astro) – responsible for developing the spacecraft bus, Observatory I&T, L&EO/30-day checkout and sustaining engineering support
- NFI Instrument Team (PSU) – responsible for XRT and UVOT instrument performance, calibration, FSW maintenance
- BAT Instrument Team (GSFC) – responsible for BAT instrument performance, calibration, FSW maintenance

The FOT consists of the Flight Ops Lead and Operations Engineers (OEs), who perform mission planning, spacecraft commanding, health & safety monitoring, data processing and accounting, and ground system management and maintenance. The core FOT is augmented by PSU Grad Students, who assist in the operations activities. The FOT is responsible for the day-to-day operation and health & safety of the observatory.

The SOT consists of the XRT, UVOT and BAT instrument scientists. XRT and UVOT members staff the MOC to perform science observation planning, instrument performance assessment and coordination of all instrument activities. The BAT members coordinate with the MOC staff for observation planning and BAT performance assessment and to provide sustaining engineering activities.

The Spectrum Astro spacecraft team develops the spacecraft bus, leads the Observatory I&T, performs launch site processing at CCAFS, and leads L&EO through the 30-day checkout, with support from the FOT and instrument teams. After successful 30-day checkout, PSU assumes responsibility for operation of the mission for the normal operations phase. The PSU Mission Director has overall responsibility for mission operations and directs MOC activities, including the FOT and SOT.

The NFI instrument teams develop the XRT and UVOT instruments, support I&T, and during normal operations perform instrument calibration, performance assessment, and FSW maintenance. Maintenance of the FSW is performed in the FSW Lab at the PSU MOC facility. Support is also provided by MSSL for the UVOT ICU, by UL and Brera for the XRT, and by SwRI for both instruments.

The BAT instrument team at GSFC develops the BAT instrument, supports I&T, and during normal operations perform instrument calibration, performance assessment, and FSW maintenance. The BAT team performs assessment of the BAT performance via remote connectivity to the MOC, and determines commanding needs for maintenance and performance tuning of the instrument. The BAT team coordinates with the SOT in the MOC to schedule

command requests, FSW loads, and to provide inputs to the science planning process. The BAT team is supported by LANL for BAT science FSW.

During the normal operations phase, the Project team includes the PI, and the Mission Operations Manager (MOM), who has responsibility to NASA for oversight of Swift operations and coordination of institutional support organizations, including NISN, SN, and FDF.

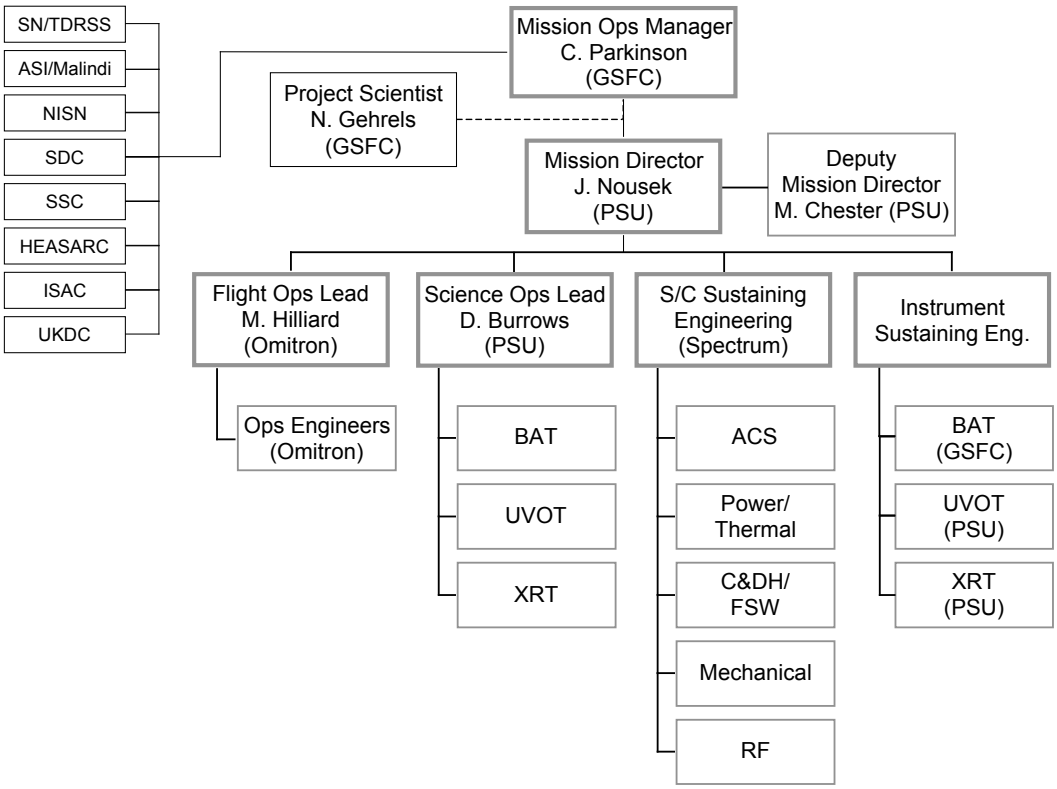

Figure 3-2: Swift Mission Operations Organization

3.3 MISSION OPERATIONS WORKING GROUP

Starting with pre-launch planning and preparations, the Mission Operations Working Group (MOWG) convenes to coordinate operations plans, operations product development, and to resolve operations-related issues. The MOWG is composed of representatives from all organizations involved in the development and operation of the observatory. Pre-launch, the MOWG is chaired by the Mission Operations Readiness Lead, with representation from the PSU Operations Lead, the Omitron development and flight ops teams, Spectrum Astro, NASA

systems engineer and communications engineer, the GNEST Lead, and the Instrument Teams. During on-orbit operations, the MOC Director chairs the meetings, supported by the Flight Ops and Science Ops Leads.

4.0 GROUND SYSTEM OVERVIEW

The Swift Ground System provides for:

- Radio Frequency (RF) communications with the spacecraft
- Spacecraft & instrument monitoring and control
- GRB alert notification
- Mission Planning
- Science data processing
- Science data archive and distribution

These functions are performed by existing and new facilities. A Swift Ground System mission architecture overview is shown in Figure 4-1.

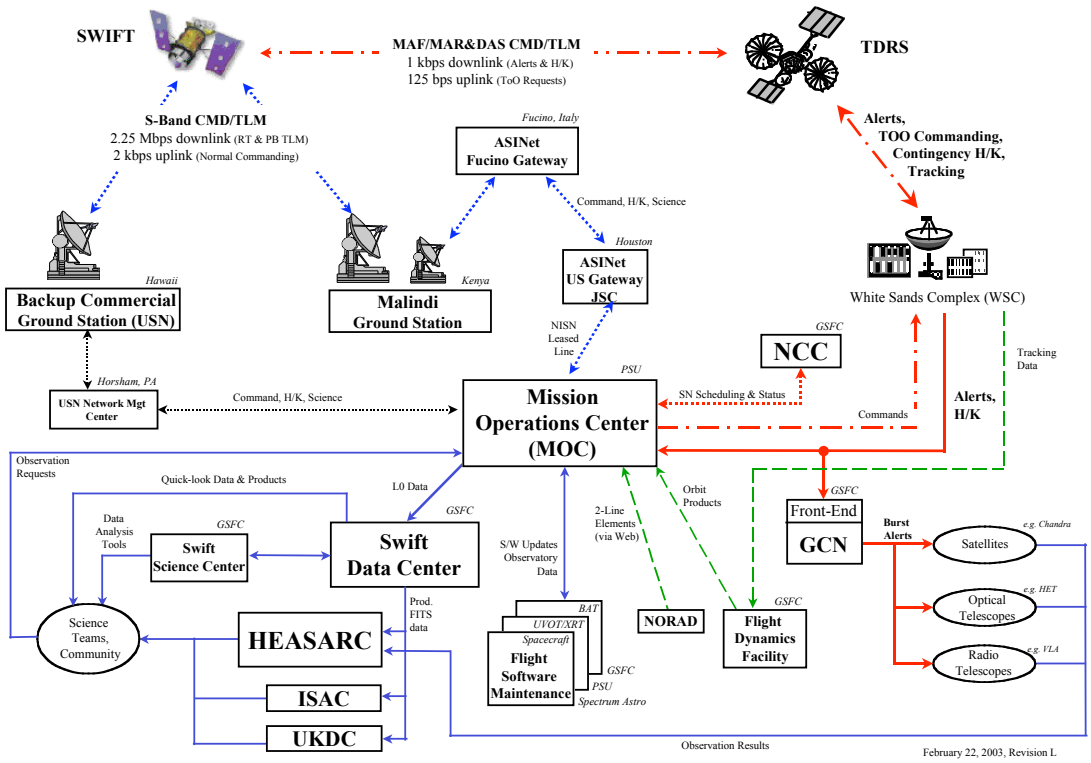

Figure 4-1: Swift Mission Architecture

4.1 MALINDI GROUND STATION

The Malindi Ground Station in Kenya provides space-to-ground RF communications with the Swift spacecraft. The station supports simultaneous S-band science and engineering data acquisition at 2.25 Mbps and S-band command (CMD) functions at 2 kbps. The ground station uplinks spacecraft CMDs received from the MOC, and provides real-time (RT) or playback (PB) S-band telemetry (TLM) and pass statistics to the MOC during each pass. The CMD and TLM data are transferred over the ASINet link between the MOC and the Malindi station. ASI provides Malindi station operations, including the transmission of TLM to and receipt of CMD from the Intelsat spacecraft. Approximately eight passes per day will be scheduled by the MOC to support mission communication requirements during nominal on-orbit operations.

4.2 TDRSS

The TDRSS DAS provides near continuous S-band downlink coverage for low rate telemetry. This service provides the downlink of GRB alerts to the ground for rapid delivery to the science community via GCN. Low rate State of Health (SOH) data can also be provided to support contingency operations and Launch and Early Orbit (L&EO). The spacecraft can determine autonomously when to transmit data via TDRSS. Quick response commanding is available via TDRSS Multiple Access (MA) forward service over S-band at 125 bps for ToO requests, contingency operations and L&EO support. The DAS will communicate information to and from the MOC via the Space Network (SN) Web Services Interface (SWSI). Use of the TDRSS service is scheduled using the SWSI to communicate via the Network Control Center (NCC) at NASA/GSFC.

4.3 COMMERCIAL BACKUP GROUND STATION

Backup Ground Station services will be provided by Universal Space Network (USN), a commercial RF communications service provider. USN's Hawaii ground station provides space-to-ground RF communications with the Swift spacecraft. The station supports simultaneous S-band science and engineering data acquisition at 2.25 Mbps and S-band command functions at 2 kbps. The ground station uplinks spacecraft CMDs received from the MOC, and provides real-time S-band telemetry to the MOC during each pass. The CMD and TLM data are transferred over a leased line link between the MOC and the USN Network Management Center (NMC). Post-pass, the recorded PB TLM are transferred over the Internet to the MOC. The NMC manages the ground station resources and network interfaces to the station, and is the point of contact for the MOC. Passes will be scheduled on an as-needed basis, and will be used primarily for L&EO support for the first 30 days of the mission.

4.4 GROUND COMMUNICATIONS NETWORK

The Swift ground communications network provides data transport between the MOC at PSU, State College, PA and several ground network interfaces. The MOC will interface with the SDC, the FDF, the BAT team and the NCC at NASA/GSFC, the White Sands Complex (WSC) in NM, the ASINet US Gateway at Johnson Space Center (JSC) in Houston, TX, the USN NMC in Horsham, PA, and the spacecraft vendor (Spectrum Astro) in Gilbert, AZ. All communication data links into and out of the MOC are the responsibility of PSU. For TDRSS support, NASA Integrated Services Network (NISN)will manage the link between WSC and GSFC, and the

MOC will utilize the NISN Internet Protocol Operational Network (IONet) services for the link between GSFC and the MOC. The internet link from the MOC to the SDC will be used for transferring Pass-Oriented Level 0 (POL0) data sets. ToO requests from the science community to the MOC are handled through a web-based form. Data-line security is predominately provided by a firewall that controls the boundaries between three separate network subnets: open, protected, and closed.

4.5 SWIFT MISSION OPERATIONS CENTER (MOC)

The MOC, located near PSU in State College, PA will operate the Swift satellite and instruments. The MOC will support pre-launch operations, launch and 30-day checkout, normal and contingency operations. PSU, under the direction of the PSU Operations Lead, has responsibility for implementing the MOC and overall mission operations. Spectrum Astro provides spacecraft bus training for the Flight Operations Team (FOT) pre-launch, and is responsible for spacecraft launch processing and initial 30-day post-launch checkout. The Science Operations Team (SOT) includes instrument scientists from the XRT, UVOT and BAT development teams. The BAT/SOT is located at GSFC, and coordinates with the MOC-based team for science planning and BAT monitoring and maintenance.

The MOC performs all spacecraft and instrument mission planning, commanding, monitoring, and pass-oriented L0 data processing and delivery to the SDC. The MOC provides rapid response for the follow-up of new GRBs detected by the BAT on-board, and ToOs input from the science team or science community. The MOC incorporates automation of spacecraft operations and data processing to permit a small operations team and "lights-out" operation, and to speed data processing and response to GRBs and ToOs. Archive of all raw and L0 data for the mission is provided off-line with rapid retrieval of the last 7 days. A 30-day on-line archive of housekeeping telemetry, command transmissions, and MOC processing statistics and status is maintained.

The MOC architecture is based on commercial- and government-off-the-shelf (COTS/GOTS) hardware and software tailored for Swift mission support, augmented by custom software. The Integrated Test and Operations System (ITOS) provides command and telemetry processing, real-time monitoring, and archiving. Satellite Tool Kit (STK) and the STK Automation software provide flight dynamics functions. Science planning is provided by TAKO, and the Mission Planning System (MPS) provides mission planning and command load generation. The Data Trending and Analysis System (DTAS) allows engineers to review spacecraft status and perform data trending from remote locations (such as Spectrum Astro, Instrument teams). The MOC automation software performs automated processing of GN passes, TDRS alerts, L0 processing and distribution, health & safety monitoring, and personnel alerts. Computer security with use of firewalls and other techniques prevents intrusion and disruption of operations.

Reference the *MOC Design Specification* document for additional information.

4.6 SWIFT DATA CENTER (SDC)

The SDC converts Swift L0 data into Flexible Imaging Transport & System (FITS) files and standard data products using an automated processing pipeline. The format of the FITS files is consistent with Office of Guest Investigator Programs (OGIP) standards. The data sets are organized by target to facilitate later scientific analysis. Quick-look data products are made on a shorter time scale using POL0 from the MOC. The SDC will create and maintain a database of results for public access through the WWW.

The SDC delivers processed production data to the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA/GSFC and to data centers in the UK and Italy, which will in turn serve them to the public. The data centers provide expertise in the scientific analysis of Swift data. The HEASARC will store all in-flight data, relevant calibration data, analysis software, and documentation.

4.7 SWIFT SCIENCE CENTER (SSC)

The Swift Science Center (SSC) assists the science community in the scientific analysis of Swift data. The SSC has the lead role in developing the software tools needed to convert Swift telemetry into FITS files and to perform scientific analysis of the Swift data. After launch, the SSC updates the analysis tools as the understanding of the techniques utilized improves with experience. In addition, the SSC maintains documentation of the Swift data and results, provides user guides, provides online data analysis recipes, and other information for use by the science community. The SSC will also help to spread the word in the lay community through outreach activities.

4.8 GAMMA-RAY COORDINATES NETWORK (GCN)

The GCN distributes location and light curve information for GRBs detected by all spacecraft capable of detecting GRBs to interested members of the science community. The rapid dissemination of Swift alerts and finder fields will enable ground observatories and operators of other spacecraft to plan correlative observations. The GCN is an existing system with sufficient capacity to support Swift. The SOT will subscribe to the GCN to receive notification of GRBs detected by other spacecraft.

4.9 HEASARC/DATA ARCHIVAL

The HEASARC is the permanent archive for Swift data products, calibration data and documentation. All data products will be placed in the HEASARC and mirror archives in Italy and the UK. These archives will make the data available electronically to everyone, regardless of affiliation. The data will be automatically processed by the pipeline as soon as it is downlinked, and will flow directly to the archives without a proprietary period, with the minimal technologically feasible delay. Data will be archived throughout the life of the mission.

4.10 INTERNATIONAL DATA CENTERS

The UK Swift Science Data Center (UKSSDC) at the University of Leicester and Italian Swift Archive Center (ISAC) at OAB, Milan archive the FITS files and standard products. They

provide ready access to the data and expertise in the analysis for local users. The SDC and SSC support these data centers as needed.

4.11 EDUCATION AND PUBLIC OUTREACH (E/PO)

Swift has a substantial Education and Public Outreach (E/PO) Program, which reflects NASA Headquarters' commitment in this area. Seven projects are included under this program to reach millions of people of all ages to capitalize on the public excitement over GRBs. These include a major web-site development, television productions, curricular materials, collaboration with teacher organizations to disseminate workshop materials, and participation in the Appalachian Region Project for under-privileged children.

4.12 SPACECRAFT AND INSTRUMENT SUSTAINING ENGINEERING FACILITIES

Spectrum Astro, in Gilbert, AZ, provides spacecraft sustaining engineering support during on-orbit operations. Systems and subsystems engineers will maintain familiarity with Spacecraft SOH status, long-term trends and ongoing operational activities. The spacecraft vendor maintains the bus FSW and supports the FOT in anomaly analysis and resolution. The high-fidelity spacecraft simulator, Hotbench, is maintained as the testbed for FSW testing and analysis. The spacecraft vendor also has remote access to MOC trending data and telemetry files to aid in analysis.

The Instrument Teams maintain facilities for sustaining engineering support of the Swift instruments. The BAT team is located at GSFC and is responsible for BAT instrument performance analysis and FSW maintenance. Maintenance of the BAT science FSW is provided by LANL. The NFI teams are responsible for XRT and UVOT performance analysis and FSW maintenance, and are primarily located at PSU, with support from MSSL, Brera and SwRI.

5.0 PRE-LAUNCH OPERATIONS PREPARATION

The pre-launch phase consists of the ground system development and validation, and operations preparation activities. The MOC team develops and tests the MOC software, sets up and configures the MOC facility at PSU, and participates in the series of ground system tests. The MOC team also prepares the operations plans and procedures, and participates in Observatory I&T, RF compatibility tests, training, and simulations and operations exercises.

5.1 TRAINING

FOT training starts with the development of a comprehensive training plan. FOT training includes formal classroom training, spacecraft and instrument systems training, documentation review, hands-on console training, simulations, and a formal evaluation and certification process. The Swift Training Plan includes instrument and spacecraft systems training by the instrument teams and spacecraft contractor, general satellite operations training, and mission-specific procedures training for Swift operations. MOC ground segment training includes hardware and software overviews and hands-on practice. Additional training on spacecraft and instrument operational requirements is obtained through FOT participation in Observatory I&T activities. Reference the *MOC Training & Certification Plan* for additional information.

SOT training begins during instrument development, including preparations for and participation in Observatory I&T. Training continues with the development of science operations plans and procedures. The SOT will also receive some formal training in the use of MOC systems for instrument operations and mission planning.

Pre-launch simulations are used to train, exercise, and evaluate FOT operators in nominal and contingency situations in all mission phases: launch, early orbit, science data collection, and maintenance functions. Pre-launch simulations include End-to-End (ETE) operations with the ground stations and spacecraft at the GSFC I&T facility, as well as internal data flows at the MOC. Post-launch, training of new FOT operators and student operators will include on-the-job-training (OJT) mentoring by experienced personnel.

Pre-launch Operations for Swift is defined as any pre-launch activities that include the use of the Swift MOC as an operational entity prior to the actual launch countdown. Ground system and operations readiness will be determined by a series of ground system tests and operations simulations. The test program and schedule are documented in the *Swift Ground System Test Plan*. Procedures for spacecraft and ground system testing will be developed to allow maximum reuse for on-orbit L&EO and normal operations phases.

5.2 OPERATIONS PRODUCTS DEVELOPMENT

The FOT plays a key role in the development of operations products and preparation for flight operations. The roles and responsibilities of the various organizations involved are described in the *Mission Operations Agreement: Swift Mission Operations Roles & Responsibilities*. The FOT will develop any Operations Procedures directly related to normal day-to-day observatory operations including the use and operation of the ground system.

The FOT develops detailed procedures for routine and contingency operations to define the steps necessary to accomplish all tasks needed to operate the observatory. The team participates in Observatory I&T to become familiar with the spacecraft subsystems, instruments, operations procedures, and to checkout the MOC systems with the actual flight hardware. The FOT participates in STOL proc validation, and develops new procs and modifies spacecraft and instrument Procs as needed to ensure they are operationally usable. Proc modifications are reviewed with the originating organization. The FOT develops ground system related procs and any flight operations-specific procs. The FOT developed the *ITOS Database Format Control Document* guidelines for use by all Swift teams to establish consistency in development of the ITOS STOL Procs and the T&C DB.

The project telemetry and command database (T&C DB) specifies all spacecraft and instrument telemetry parameters and commands that are used by the ITOS system. Individual ITOS T&C DBs are developed for the spacecraft and each of the instruments by the development teams and validated during the respective I&T. These DBs are brought together in Observatory I&T to form the Observatory DB. The MOC inherits responsibility for the Observatory T&C DB after on-orbit delivery of the spacecraft by Spectrum Astro.

For all procs that require validation on the MOC system, the FOT will be responsible for executing the procs and validating that they are running properly on the MOC system (i.e., that they are running the same in the MOC as they were running in I&T). For spacecraft procs developed by Spectrum, Spectrum is responsible for directly participating in the proc validation process in the MOC with the FOT, and shall share responsibility with the FOT that the proc is achieving the intended results. Spectrum shall determine for each spacecraft proc if the HotBench Simulator, the observatory, or a combination of the two, is appropriate for validation. Ultimate and final determination that a spacecraft proc running in the MOC is achieving the desired results with the spacecraft is the responsibility of Spectrum. Validation of spacecraft-related procs developed by the FOT are subject to the approval of Spectrum, but are ultimately the responsibility of the FOT.

For instrument procs, the SOC and Instrument Teams shall provide the same type of support to the FOT as described above for Spectrum. Ultimate and final determination that a proc running in the MOC is achieving the desired results with the instrument is the responsibility of the SOT and Instrument Teams. As noted above, validation of instrument-related procs developed by the FOT is the responsibility of the FOT.

The FOT develops configuration monitors (configmons) that check specific spacecraft and instrument configurations based on comparison of telemetry parameters against expected values. The spacecraft and instrument teams coordinate with the FOT to define the configmons. The FOT also develops display pages for monitoring of telemetry parameters. Spacecraft and instrument developed display pages will be reused as appropriate. The spacecraft and instrument teams also define the subset of telemetry parameters that are to be trended in the MOC. These telemetry parameters will be loaded into the DTAS trending system.

The Launch and Early Orbit timeline and script are developed jointly by the spacecraft, instruments, FOT, SOT and Mission Operations Readiness Lead to define all necessary steps to

activate and checkout the observatory after launch. The L&EO timeline is the responsibility of Spectrum Astro, and the L&EO script is the responsibility of PSU.

5.3 OBSERVATORY I&T

At approximately L-12 months, a MOC system is configured at GSFC to support Observatory I&T conducted by Spectrum Astro. The FOT will participate alongside the spacecraft and instrument teams to support problem resolution with the MOC command and telemetry system, and for testing and confirmation of the MOC command and telemetry database. The main goal in supporting this testing is to allow the FOT access to actual telemetry and become familiar with both the spacecraft and instruments which reduces risk for later ground system testing and operations.

5.4 RF COMPATIBILITY TESTING

RF Compatibility tests will verify the compatibility between the spacecraft and the ground communications systems (TDRSS, Malindi, and USN). All RF testing will be conducted when the spacecraft is in the Observatory I&T facility at GSFC. The ground stations will provide portable RF test equipment to interface with the spacecraft and the MOC. The TDRSS RF Compatibility testing will utilize the Simulations Operations Center (SOC) at GSFC, the Compatibility Test Van (CTV) to communicate with a TDRS, the DAS at WSC, and forward data to the MOC at GSFC.

5.5 SPACECRAFT INTERFACE TESTING

Spacecraft Interface Testing will verify compatibility between the observatory (spacecraft and instruments) and the MOC system. Testing will include real-time telemetry and commands, loads, data and memory dumps, and Burst Alert/TDRS messages. Spacecraft Interface Testing will initially receive telemetry in a “listen-only” mode from the spacecraft during spacecraft I&T (at Spectrum Astro facility) and observatory I&T (at GSFC). The Spectrum Astro Hot Bench simulator will be utilized to ensure that all obvious interface problems are found and resolved prior to the use of the spacecraft.

5.6 MISSION READINESS TESTING

Mission Readiness Tests will verify that all ground systems, interfaces, and operations elements meet the mission requirements. These integrated system verification tests are conducted prior to the ETE tests and mission simulations. During this test phase, certain tests may be repeated as needed to maintain readiness. The FOT plays an integral role in the definition, execution, and analysis of these tests. The MRTs are the responsibility of and coordinated by the Ground System Test Lead.

5.7 END-TO-END (ETE) TESTING

ETE tests involving all ground system elements verify a proper data flow configuration between the spacecraft and the MOC. The elements include the spacecraft (at the GSFC I&T facility), ground station RF equipment (at the GSFC I&T facility), the SN, the MOC equipment loaded at

PSU, and the SDC at GSFC. Commands are sent from the MOC through the RF equipment to the spacecraft. Similarly, telemetry is sent from the spacecraft through the RF equipment to the MOC. Burst alert processing is verified through the SN. Finally, the MOC transfers L0 science data to the SDC. All practical operational data flows and processing steps are exercised and verified.

Further ground system ETE tests are performed between the MOC and ground stations to verify proper configurations between the ground stations and the MOC. To test a ground station to MOC interface ETE, recorded data is played back from the ground station to the MOC. MOC commands are sent to the ground station, and recorded for subsequent verification.

5.8 MISSION SIMULATIONS

Mission Simulations will be designed to emulate the operations environment of different mission phases, including L&EO, nominal science collection, and spacecraft maintenance activities. The focus of mission simulations will be the continued training of the FOT, SOT, Spectrum Astro, and ground system support teams, procedure validation, database verification, and system testing in the actual operations environment. There are plans for three Mission Simulations tests for L&EO, normal, and contingency operations. L&EO simulations are basically rehearsals of the L&EO timeline that exercise the launch scripts. Normal operations simulations generally rehearse a typical day-in-the-life once the spacecraft has been declared operational. Contingency simulations are rehearsals of various anomaly situations that may occur on-orbit. NASA will provide lead support in planning, documenting, and conducting all operations simulations needed prior to launch. This support will be provided primarily by the Mission Operations Readiness Lead. NASA will ensure that the collection of simulation activities prior to launch demonstrates the overall readiness of the operations staff, products, and processes. Refer to the *Mission Operations Readiness Plan* for additional information.

6.0 LAUNCH AND EARLY ORBIT (L&EO) OPERATIONS

The early orbit checkout phase begins at launch and is scheduled to complete in the first 30 days of the mission. Spectrum Astro conducts launch and 30-day checkout from the PSU MOC. The L&EO Director will be provided by Spectrum Astro and will generally be the lead in all aspects of mission operations during the L&EO phase. The FOT supports these activities by executing the command and control interface to the spacecraft, scheduling ground station and TDRSS support, and performing other activities which are part of nominal operations. The SOT and personnel from the BAT team support instrument activation and verification steps in the L&EO timeline. Coordination of activities and resolution of conflicts will be the responsibility of the L&EO Director.

Launch operations begin with the start of the defined launch countdown. Prior to launch, pre-launch activities are controlled from Kennedy Space Center (KSC) with launch readiness status provided to the FOT on a regular basis. Final checkouts are performed pre- and post- mate to the Boeing Delta II 7320 launch vehicle. After Delta 7320 nose-cone closeout (L-TBD hours), insight into the spacecraft status is limited to a small number of hardwired safety-critical parameters and commanding is precluded. Pre-defined launch phase procedures describe actions to be taken by Spectrum Astro Launch Processing team in the case of nominal and non-nominal spacecraft status. As part of the launch countdown, the MOC Director will report the readiness to support launch of the MOC and its communication links. Similarly, the GNEST Lead will report the readiness of the remainder of the ground system. .

There is no telemetry or command capability from liftoff until the first contact with the spacecraft via TDRSS. The Spectrum Astro and MOC personnel have no insight into the spacecraft or instruments status until the first on-orbit contact. At that time, the MOC will receive real-time data as well as housekeeping data recorded since spacecraft initialization following separation. Launch control center personnel will keep the MOC informed of launch status and will provide the orbit insertion vector.

During the initial ground contact, Spectrum Astro engineers and MOC personnel will checkout the following:

- Initial SOH verification
- Verify attitude orientation, current/voltage as expected
- Initial command verification
- Verify Solar Array and Antenna Boom deployments
- Download stored SOH telemetry

The FOT will schedule ground contacts utilizing all available Malindi passes, augmented by USN/Hawaii passes and TDRSS contacts to maximize spacecraft contact time. Operations during the early orbit mission phase will be controlled by pre-defined, certified procedures and focus on verifying spacecraft and instruments' health and proper configuration. Operations during this phase are lead by Spectrum Astro and supported by the FOT, SOT, and instrument teams. The MOC will be manned continuously until completion of the 30-day checkout. The FOT provides support as necessary during this period.

All spacecraft and instrument systems are verified for nominal functionality during the 30-day checkout. A timeline of checkout activities will be created from inputs from Spectrum Astro and the instrument teams. Spacecraft and instrument operating modes are validated, operational procedures are updated based on flight system characterization, and the trending of system data is initiated. The culmination of the checkout will be a declaration by Spectrum Astro that the spacecraft functionality and interfaces have all been validated and NASA accepts the delivery on-orbit. The declaration will be followed by a Project-level review to assess post-launch and operational performance of the spacecraft, instruments and ground segment. At the conclusion of a successful checkout, responsibility for spacecraft operations is handed over from the Spectrum Astro operations team to PSU. The FOT will then have responsibility for operating the spacecraft and instruments and overall mission planning, while the SOT will have responsibility for the performance of the instruments and science planning.

The USN ground station will be utilized for L&EO support only. Scheduling of USN resources will be performed manually via voice between the MOC and the USN NMC. Any additional support will be arranged and negotiated on an as-needed basis.

7.0 NORMAL ON-ORBIT MISSION OPERATIONS

7.1 OVERVIEW OF NORMAL ON-ORBIT OPERATIONS

Normal operations begin at the conclusion of the 30-day checkout, and encompass all activities necessary to collect and process science data and maintain the spacecraft, instruments, and ground systems on a routine basis. The normal operations phase is planned to terminate 2 years after launch, unless the mission life is extended.

The majority of Swift's observing timeline is spent on observations of GRB afterglow. The pre-planned science timeline is revised daily during the five day work week in response to new bursts and ToOs. The pre-planned observations will be stored and managed by the spacecraft stored command processor (SCP) and will provide a means of performing multiple observations without ground commands. The most critical spacecraft activity occurs after a burst trigger. When a GRB is detected by the BAT, an alert and a subsequent location telemetry message is sent to the ground via TDRSS to the GCN and the MOC, then automatically to the GRB community. Once the BAT determines the location of the GRB, the FoM will coordinate between observing the newly detected GRB and the pre-planned targets, using a merit value comparison. Pre-planned targets have ground assigned merit values and newly detected GRBs will be assigned merit values onboard. If the FoM determines that the new target is more meritorious, it will send the spacecraft a request to slew. The spacecraft makes final checks on constraints and critical actions. The slew decision, BAT burst location and light curve, XRT position and spectrum, and UVOT postage stamp finding chart are relayed through TDRSS as they become available.

The spacecraft actions following a burst are autonomous through the initial set of observations to obtain multi-wavelength light curves and energy distributions. The on-board decision process may be revised after launch as appropriate to optimize burst characterization and follow-up observations. When observations are finished or the new burst can no longer be observed (e.g., due to Earth occultation or other constraints), the satellite returns to its pre-burst mission timeline at the current time. During staffed hours, the on-duty MOC science planner and mission-planning engineer determine if the mission timeline should be revised based on the burst's initial characteristics and consideration of observations preempted by the new burst. At all other times, the on-call science planner will be paged to examine the burst’s characteristics to determine if an immediate replan of the mission timeline is warranted. If the science planner determines that the burst is of high priority, then the on-call FOT engineer will be paged and requested to uplink a revised science timeline.

The TDRSS DAS provides near continuous downlink coverage for downloading GRB alerts and finding charts for delivery to the GCN and for alerting the ground of spacecraft emergencies. Alarm messages, in standard-format state-of-health telemetry, are autonomously sent to alert the ground of critical alarm events such as safehold or low voltage. On ground initiated command, real-time housekeeping data can also be transmitted for spacecraft and instrument monitoring and contingency support.

Swift will respond to other scientific opportunities, which includes GRBs detected with other satellites, X-ray transients, and unusual behavior from known sources. Anyone in the astronomical community is able to submit a ToO request for observations by sending a brief, scientific justification to the MOC via a web form. The SOT are paged for those requests that require immediate action, and notified via email otherwise. Each ToO request is evaluated by the PI or his designated representative from the Swift Science Team to decide whether to interrupt the pre-planned schedule. Acceptance of ToO requests requiring rapid response is expected no more than once a week.

Approximately eight ground station passes per day will be scheduled by the MOC to support mission communication requirements during nominal on-orbit operations. The FOT manages data storage on the SSR and its downlink via the Malindi ground station. Full science data downloaded through ground passes provide more detailed information about the afterglow. Automated processing of the telemetry stream begins with the production of L0 data at the MOC, and continues through a production data pipeline developed and maintained by the SDC, with associated data centers in the UK and Italy. POL0 products will be delivered to the SDC within 45 minutes of the MOC's receipt of the telemetry, and standard data products posted to the MOC's web site periodically (see Table 7-1). Complete sets of standard data products will be deposited in the HEASARC within two weeks. Science analysis tools are provided and maintained by the SSC.

Table 7-1 MOC Products Posted to the Web

Product	**Update Frequency**	**Retention Period**
Pre-planned Science Timeline	Each Update	30 days
As-flown Timeline	Daily	30 days
Contact Schedules	Each Update	1 week
TLEs (current set and cumulative log)	Each Update	LoM
TLM Statistics	Each Pass	LoM
Command Logs	Each Pass	LoM
S/C Clock Update Logs	Each Update	LoM
MOC Documentation (User's Guide, Procedures, …)		LoM

7.2 MISSION PLANNING AND SCHEDULING

The FOT and SOT perform mission planning and scheduling during the regular 5-day operations shift (reference Figure 7-1 for the "Mission Planning & Scheduling Operational Flow"). Scheduling several days in advance is expected to accommodate planning for weekends and holidays. These pre-planned schedules are revised approximately daily to accommodate new GRBs in the science target list. Key planning information begins with a science target schedule and regular spacecraft activities, and includes target occultation, accommodation of operational exclusion zones, passage through the South Atlantic Anomaly (SAA), and available Malindi ground station passes.

Guidelines for mission science planning are provided by the Swift Science Team. Guidelines include criteria for prioritizing GRBs and ToOs and strategies for follow-up observations. Criteria include the scientific importance of the GRB or ToO and assessment of efficiency for viewing based on operational constraints. The importance will depend on the GRB's characteristics, including observed source fluxes, light curves, spectra, and characteristics of the likely optical host. These guidelines will be updated based on contingency analysis of Swift and follow-up data.

The SOT selects targets and prepares a preliminary schedule based on science requirements and observing constraints in an attempt to optimize viewing times. The SOT will utilize burst alert and POL0 data products for the generation of the science timeline. The BAT team will provide additional targets to ensure sufficient coverage of the all-sky survey. The SOT generates and provides the science timeline to the FOT. The FOT will generate the mission timeline based on the science timeline, ground station and TDRSS contact schedules, and any engineering activities. This planning results in generation of time-tagged command loads for uplink to the spacecraft.

Malindi ground station contact scheduling is based on predetermined criteria (minimum length of pass, number of passes per day, maximum time between passes, etc.) and an updated orbit vector. The Malindi ground station provides the pass schedules covering 15 days to the MOC. A new schedule will be generated for each TLE update from the MOC, or for any change in Malindi support due to maintenance, downtime, or support for other missions. The scheduling procedures for use of Malindi will be documented in the MOC to Malindi ICD. Emergency supports will be coordinated with the Malindi ground station via voice links.

The SWSI is the FOT interface into TDRS scheduling and real-time monitoring. The SWSI will be used to schedule near continuous 24 hour TDRS DAS support, monitor schedule changes, receive alert information, and receive service status data. TDRS hand-over schedules are obtained from SWSI for use in mission planning and subsequent uplink to the spacecraft for antenna selection. The SWSI will also allow the FOT to schedule TDRSS MA forward supports using the WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC). The FOT shall provide orbit vectors to the SN using SWSI.

When GRB alerts or ToOs are received outside of the regular 5-day operations shift, the MOC system will utilize pre-defined criteria to determine if the on-call SOT duty scientist is paged.

Based on the information received and established guidelines, a decision is made whether to respond with a quick schedule revision or wait until the next regular shift. In the event the ToO or GRB event is determined to be of high priority and a quick response is required, the SOT duty scientist will page the on-call FOT duty engineer to generate and uplink a ToO command or revised PPST. For a ToO command, the FOT duty engineer will schedule TDRSS MA forward service with the SN via voice for rapid turnaround. The minimum time to obtain the forward link service is expected to be about 15-20 minutes. For a schedule replan, the SOT duty scientist provides a revised PPST to the FOT duty engineer, who generates the command load and uplinks the load during the next available Malindi pass. A special request for an additional Malindi contact may be needed. For a non time-critical ToO or GRB, the SOT will incorporate them into the normal planning cycle during the next regular shift. High priority events are limited to one per week.

Swift mission planning and scheduling activities require time-tagged orbital event lists based on propagated Swift orbits. During the first week of the mission, FDF support will be provided to perform orbit determination from tracking data. The tracking data will be obtained through current TDRSS tracking services. The FDF will provide orbit products to the MOC. This interface will be further defined in the Swift Project Service Level Agreement (PSLA).

Once FDF support is completed, Swift orbit determination will use North American Air Defense Command- (NORAD) provided two-line elements (TLE). NASA/GSFC continually receives the latest NORAD "satellite catalog" of up-to-date satellite state vectors in the form of TLEs. NASA/GSFC Orbital Information Group (OIG) publishes these elements on the WWW. The MOC automatically checks for new TLEs and downloads them for use in the planning systems. Once updated orbit information is obtained, the MOC will provide updated state vectors to the Malindi ground station and SN.

When GRBs are detected, the Swift spacecraft may autonomously slew to directly point the NFIs at the burst based on calculations by the FoM software on-board. These autonomous operations result in changes to the planned timeline generated by the MOC planning and scheduling function. The MOC produces an as-flown timeline for each day of the Swift mission to enable analysis of the downlinked science and engineering data for planning additional Swift afterglow observations. The as-flown timeline contains a time-ordered list of target names, target positions, instrument configurations, maneuver times, and orbital events affecting available observing time. The MOC also produces a time-on-target report to aid the SOT in assessing coverage of scheduled target observations.

MOC activities will primarily be set up on a weekly schedule (see Figure 7-2). Due to single shift operations, most FOT activities occur during typical business hours. Generation of command loads will typically occur each day of the workweek. Daily revised schedules are anticipated based on the expected frequency of GRB detections.

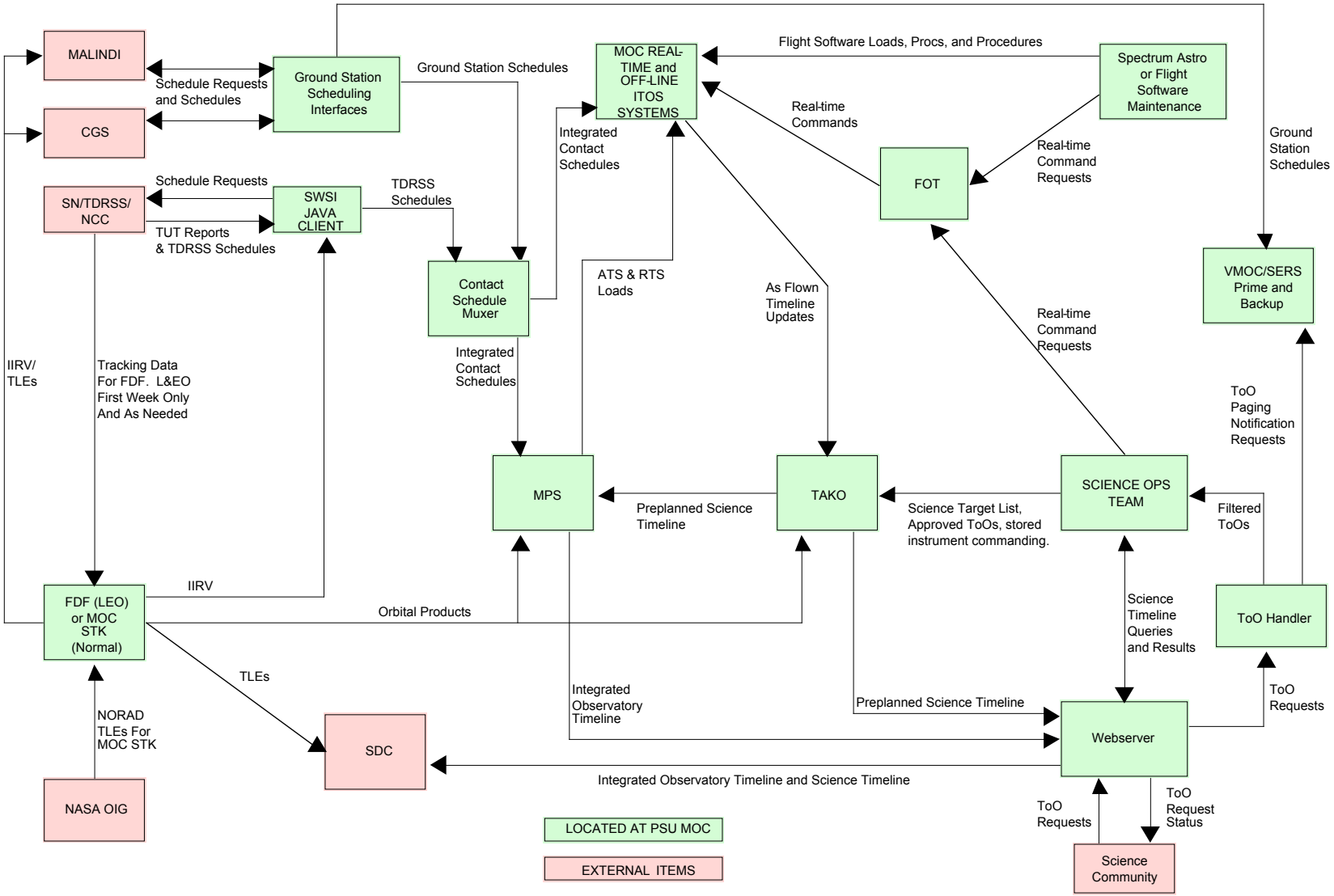

Figure 7-1: Mission Planning & Scheduling Operational Flow

7.3 ROUTINE OPERATIONS ACTIVITIES

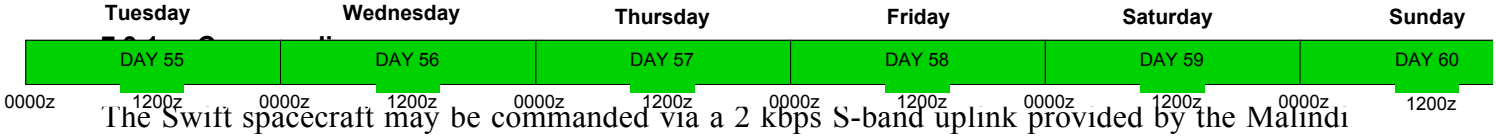

Figure 7-2: Mission Planning – "A Week in the Life of Swift"

The Swift spacecraft may be commanded via a 2 kbps S-band uplink provided by the Malindi ground station. Swift may also be commanded via a 125 bps uplink provided by TDRSS MA forward services. Quick response commanding is scheduled through the TDRSS for contingency and L&EO operations, and for ToO commanding.

Pre-planned command activities during ground station and TDRSS contacts. These procs provide a set of command operations which are prepared and checked out pre-launch and maintained under configuration control. The use of STOL procs together with the MOC automation software enables automation of routine operations during off-shift periods. The spacecraft and instrument command and telemetry database is maintained at the MOC. The database identifies critical commands, which could pose a potential danger to the spacecraft or any of the three instruments. Protection is provided to prevent unintentional use of these critical commands.

Three types of spacecraft commanding are used for the Swift spacecraft:

- Real-time commands
- Stored Command Processor (SCP) Absolute Time Sequence (ATS) table loads

Real-time commands are uplinked from the MOC for immediate execution during spacecraft ground station or TDRSS contacts. During normal operations, real-time commanding can consist of nearly any spacecraft activity. During normal operations, real-time commands will primarily consist of ATS and RTS table loading, SSR redumping activities, clock correction factor updates, and instrument parameter updates. Real-time commanding may also be needed in contingency operations for anomaly resolution or safe-guarding. Swift uses the Consultative Committee for Space Data Systems (CCSDS) Command Operation Procedure - 1 (COP-1) protocol to verify receipt of real-time commands during a ground station contact. For TDRSS contacts, receipt of real-time commands is confirmed by end-item telemetry verification. The MOC maintains an electronic log of real-time commands that have been sent and verified. An updated log covering one day of commanding is provided to the SDC within seven days of command execution.

For other than real-time commanding, the spacecraft utilizes SCP ATS table loads. These ATS loads contain time-tagged sequences of commands and are used for the majority of commanded functions on-board the spacecraft. These functions can consist of nearly any spacecraft activity, but will primarily consist of ground station contact sequences, instrument observation sequences and configuration, and various health and safety operations. The ATS loads are uplinked on a daily basis via real-time commands when the MOC is staffed and consist of at least three days of time-tagged commands. The MOC verifies all ATS command loads against operational

constraints prior to uplink. Successful uplink of an ATS command load is confirmed by a checksum operation on the entire contents of the ATS load.

For commonly used command sequences, the spacecraft utilizes SCP RTS table loads. These RTS loads contain relative time-tagged sequences of commands. The spacecraft flight software, real-time command, or ATS command can execute or start RTS loads. The RTS loads are uplinked on an as needed basis via real-time command when the MOC is staffed.

7.3.2 Spacecraft & Instrument Monitoring

The MOC is responsible for spacecraft and instrument health and safety monitoring, as well as the verification of nominal mission execution and system status. The MOC monitors received SOH telemetry for out-of-limit situations, and proper spacecraft and/or instrument configuration. STOL procs and scripts with ancillary software tools allow automation of telemetry monitoring to not only support off-shift periods, but to optimize MOC staffing during the regular 5-day shifts. This allows a small FOT cadre to perform mission planning and scheduling as well as spacecraft and instrument monitoring, and other duties such as ToO support (reference Figure 7-3 for the "Real-Time Operational Flow"). Automated telemetry processing includes packet extraction, engineering unit conversion, limit checking with alarms, display, and rules verification. The MOC automatically monitors the execution of the planned observation schedule and generates alerts for deviations. The MOC also monitors for TDRS alerts indicating GRB events or spacecraft or instrument emergency or error conditions.

The MOC responds to many out-of-limit situations automatically. During off-shift periods, paging is used to notify on-call and backup FOT and SOT personnel of situations requiring operator intervention. The on-call and backup operators have remote access to review system data or burst messages and quick-look analysis. If warranted, they are within close proximity allowing travel to the MOC for performing additional analysis or command operations.

The SOT utilizes science workstations in the MOC to receive and process telemetry, perform analysis tasks, and perform science observation planning. Instrument Teams may have instrument-specific software running on their science workstation to perform tasks specific to that instrument. The ITOS will also be running on the science workstations to decommutate engineering telemetry and provide displays. The Instrument Teams may also have remote instrument-specific science workstations external to the MOC to receive and process telemetry and perform analysis and monitoring tasks.

7.3.3 Recorder and Memory Management

The spacecraft has two locations for storing telemetry data: CPU Random Access Memory (RAM) circular buffers and the Solid State Recorder (SSR). Spacecraft SOH data are written to the CPU RAM as well as the SSR partition as a backup in the event the FSW reboots.

The SSR has a storage capacity of 32 Gigabits. The SSR is partitioned into five virtual recorders (S/C SOH, BAT Science, UVOT Science, XRT Science, and Instrument High Priority). Data are downlinked each Malindi pass by stored commands. One telemetry frame is retrieved in a round-robin fashion from each virtual recorder that is enabled and downlinked until each virtual

recorder has no more telemetry frames. The status and progress of the SSR dump for each virtual recorder is received in real-time SOH data.

Once data are processed at the MOC, the FOT evaluates automatically-generated quality reports to determine if data should be redumped. The redump commands may be programmed into the ATS for automated redumping. If there is no time to update the ATS, the FOT shall manually

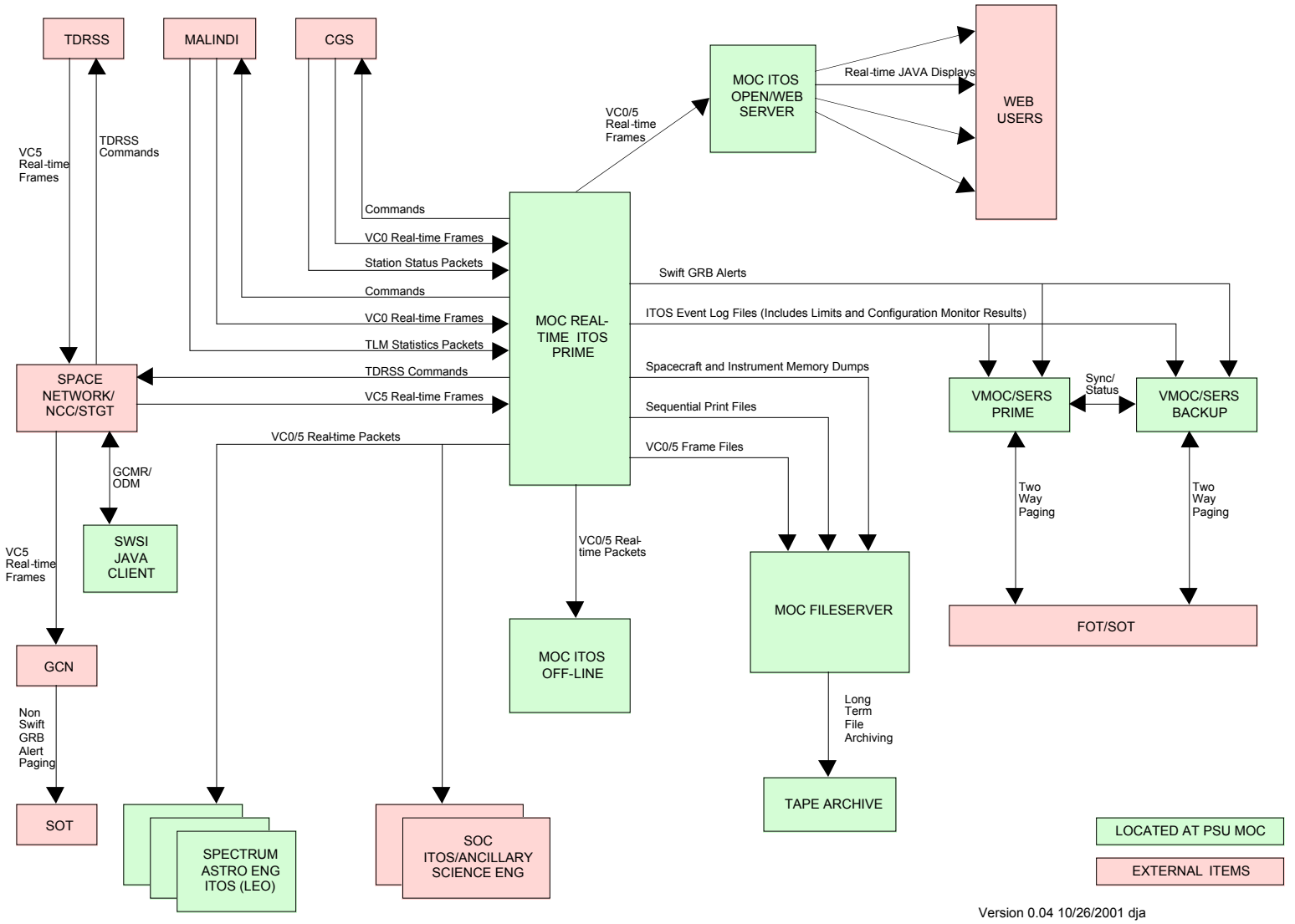

Figure 7-3: Real-Time Operational Flow

redump the needed portions of the SSR via ITOS proc. Dumping of current SSR data will be stopped while a redump of the SSR is being performed.

7.3.4 Spacecraft Clock Management

The spacecraft clock will be set close to UTC once the spacecraft is turned on after launch. Stored commands will be used to fine-tune the accuracy after the initial setting. Only the seconds field can be changed by software command. Once the clock setting is acceptable, a time correlation measurement is made to establish the initial UTC correction factor and the initial UTC starting point for future correlation duration measurements. The initial clock setting should not gain or lose more than 10ms/day which is negligible for scheduled events.

The Malindi ground station will time tag telemetry frames with the current UTC reception time. The FOT will periodically correlate the spacecraft clock to UTC from the telemetry received from Malindi. The time stamp in the secondary header of the telemetry frame represents the transmission time from the spacecraft. The UTC reception time is then corrected by subtracting the delay times due to transmission from the spacecraft and reception at Malindi. The current UTC correction factor is added or subtracted from the transmission time to get what the spacecraft thinks is the correct UTC time. The transmission time and reception time are then compared to one another to establish the delta between them. If the difference is greater than 200 μs then the correction factor is updated with the new difference and the result is uploaded to the spacecraft by the FOT on a once per weekday basis. The UTC correction factor can be adjusted at intervals of 20 μs.

Several measurements will be used to trend the drift in the spacecraft clock. Once a definable trend can be established then corrections can be made using the UTC interval adjustment register. The UTC interval adjustment register represents the number of 20 μs ticks before the subseconds field of the UTC correction factor is incremented or decremented by one. This allows the spacecraft to autonomously adjust the correction factor throughout the day to account for offset in the base oscillator frequency.

7.3.5 Ephemeris Updates

The spacecraft Attitude Control Subsystem (ACS) has been designed to perform its functions autonomously. However, it relies on near-daily ephemeris updates from the MOC in order to maintain attitude knowledge that affects fine pointing capability. Current orbit vector data consisting of position, velocity, and an epoch time is generated based on TLEs. A validity check is performed by the FOT on each new TLE set received prior to using for ephemeris updates. The ephemeris update command is included in the ATS during the load generation process. When the ACS receives the vector, it replaces old data with the new data. It begins propagating the data that is seen in the downlinked telemetry data. When the spacecraft goes to Safehold mode, the ACS has no knowledge of its position. An ephemeris message is uploaded for attitude knowledge and control.

7.3.6 ToO Requests

ToOs are submitted to the MOC using a web-based form. The decision whether to disrupt planned science operations to observe the ToO is made according to guidelines approved by the Swift PI. The MOC acknowledges receipt of each ToO within an hour, and will inform the ToO requester of its decision within 24 hours. An electronic log is also maintained showing all ToOs received and their disposition. The SOT will be notified via e-mail for each ToO and via page if time critical.

Assessment of a ToO includes: the need for rapid response, the scientific merit and goals of the ToO, the credibility of the request, and its impact on spacecraft resources and ongoing operations. The SOT provides a technical evaluation to the Swift PI. Following a decision by the Swift PI or his representative to observe the ToO, the SOT responds to include the ToO in the operational timeline. Depending on how rapid a response is needed, the position and merit can be uploaded to the Figure of Merit (FoM) via a real-time command or a short-term revision of the schedule can be uploaded via TDRSS or ground contact.

7.4 OFFLINE ACTIVITIES

7.4.1 Data Processing and Delivery

The MOC shall receive all CCSDS-compliant telemetry frames from the Malindi ground station and the TDRSS Demand Access Service (DAS) link (reference Figure 7-4 for the "Offline Operational Flow"). Pass-Oriented L0 (POL0) products will be generated on all mission telemetry and maintained within the mission archive at the MOC. The L0 processing functions include the decoding of transfer frames, the extraction of CCSDS packets sorted by Application Process ID (APID), and the creation of L0 products with associated quality and gap accounting.

POL0 products are generated for each ground-station contact. The MOC creates POL0 data sets and distributes the products to the SDC within 45 minutes after receipt of data from a ground-station contact. The MOC will forward the data products electronically to the SDC for further processing. The MOC will also notify Instrument Teams of the availability of specified L0 data products.

The SOT analyzes the Observation-Oriented Level 0 (OOL0) data from the SDC for science planning and verification of proper instrument function. Any out-of-limit conditions or abnormal spacecraft or instrument function are assessed and responded to using pre-approved procedures, wherever possible.

7.4.2 Trending and Analysis

The MOC also performs selected trending of housekeeping and engineering parameters to verify nominal system performance and expected degradation. The Data Trending and Analysis System (DTAS) provides the capability for the user/client to view plots and tables of the housekeeping and trend data and save these products to a file. Each Instrument Team and Spacecraft Sustaining Engineering will have the DTAS client application software installed on a user workstation using an install shield that can be downloaded via the MOC web site. The

client application consists of a Trending Tool and an Analysis Tool. The Trending Tool allows a user to plot individual mnemonics vs. time including min, max and mean. The Analysis Tool allows the user to view tables, plots, statistics and compare data. Additional details of the DTAS capabilities can be found at:

`http://radlab.gsfc.nasa.gov/DTASHome.html`

7.4.3 Data Accountability

The MOC is required to provide at least 95 percent of received telemetry in the form of POL0 data sets. A log of data received, processed, distributed and quality control information is maintained. The total ETE mission data loss is expected to be less than 10%. The MOC's Frame Accounting software generates and logs statistics and gap information for all telemetry frame files received at the MOC. The gap information is used by the FOT to determine if redumps are required and which frame ranges need to be redumped. The ITOS system also generates packet statistics for all POL0 files. The statistics are posted to the MOC's web site for easy access.

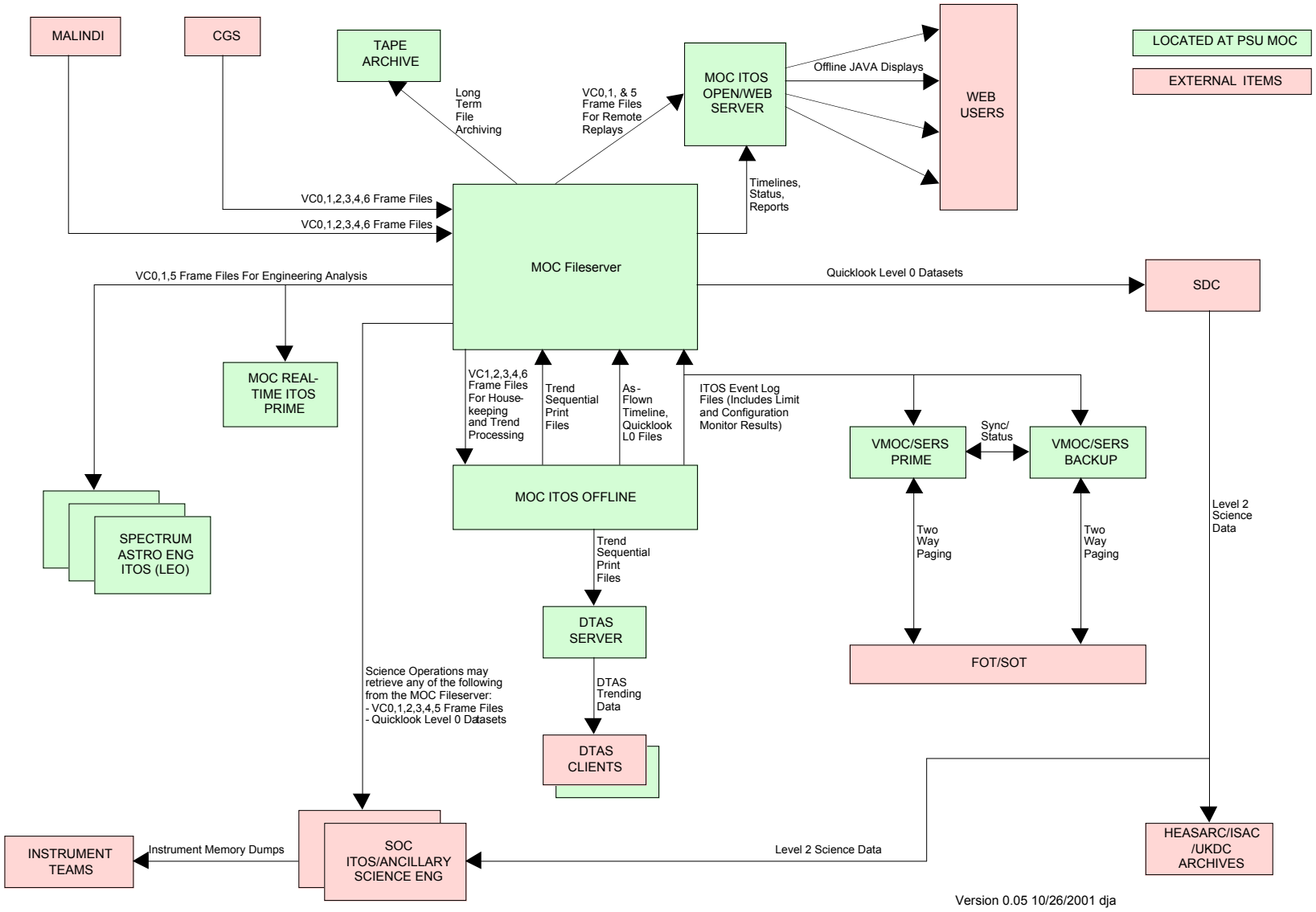

Figure 7-4: Offline Operational Flow

7.5 MAINTENANCE FUNCTIONS AND SUSTAINING ENGINEERING

Day-to-day spacecraft operations at the MOC includes the monitoring of real-time and playback spacecraft housekeeping telemetry and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various spacecraft systems, and performs a weekly systems analysis per defined procedures.

Spectrum Astro will be retained for the duration of the Swift mission to provide routine sustaining engineering support to the FOT. A remote engineering workstation will allow engineers to review spacecraft status and trend data from the MOC data archive. Sustaining Engineering support would include, for example, expert systems engineering analysis, solar array degradation over time, battery performance characterization, and thermal degradation. The contractor submits periodic spacecraft system status reports to the MOC based on review of received housekeeping data. The contractor is also on-call to support anomaly resolution activities, as required.

Spectrum Astro will maintain the flight software for the spacecraft. Any changes to the flight software are validated before uplinking the software for execution. The Swift Project Configuration Control Board (CCB) will ensure that all changes are proper and that earlier versions of the software are available if anomalies are identified in subsequent versions. A flight software testbed (Swift Hotbench) may be used to validate planned updates to the spacecraft flight software.

Day-to-day instrument operations at the MOC includes the monitoring of real-time and playback instrument housekeeping telemetry and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various instrument systems, and performs a weekly systems analysis per defined procedures. Analysis of POL0 science data in the MOC tracks instrument performance as the mission progresses, and helps detect any subsystem problems.

The instrument teams provide sustaining engineering support for the Swift instrument complement. Remote access to the MOC archive data allows the instrument teams to review instrument housekeeping data, analyze POL0 science data, and perform trending of selected subsystem parameters. The instrument teams also have local presence at the MOC to verify proper instrument performance. Sustaining engineering and calibration activities are clearly defined pre-launch, and executed and supported on a routine basis by the instrument teams. A periodic report on instrument system status is provided to the MOC, and appropriate information provided to the SSC to support data analysis of Swift data by the science community. Instrument teams and software personnel are also on-call for anomaly resolution support.

Instrument flight software will be maintained by the instrument teams, who will perform configuration control and validate changes to the software loads. Once the loads are validated, they are transferred to the MOC for uplink. The MOC will validate correct instrument destination, check for critical commands, and verify correct uplink of the loads to the spacecraft.

Sustaining engineering activities for the MOC include periodic upgrade and testing of the MOC hardware and software systems, and maintenance and CM of the T&C DB, procs, display pages,

configmons, ops procedures and MOC documentation. . Data quality monitoring aids in the identification and resolution of hardware degradation in the systems, and configuration management of software and hardware at the MOC ensures efficient, sustained operations. Maintenance contracts are in place with MOC COTS vendors to cover bug fixes, consulting support, and software upgrades for the life of the MOC mission.

The MOC will be responsible for maintaining the configuration of the MOC hardware, software, documentation, display pages, Project Database (PDB), as well as any other items requiring control. The Swift Project CCB will approve changes prior to implementation. The MOC will validate and test certain updates prior to implementation.

Sustaining engineering functions for the ground network and RF ground stations are the responsibility of the contracted service providers. A sustaining engineering plan will be obtained from each service provider to ensure acceptable practices are in place.

7.6 CONFIGURATION MANAGEMENT

All software, scripts, databases, documentation and parameter data files are maintained under configuration control. Configuration management (CM) is provided by the Configuration Control Board (CCB), either at the GNEST level or internally at the MOC level. GNEST CM is described in the *GNEST Project Management Plan*. The operations concept, ICDs, requirements, and security plan are controlled within the GNEST CCB; all other software and documentation is controlled within the MOC team. The CVS configuration management tool is used to manage the versions and track changes to the files. The MOC CM process and instructions for use of the CVS tool are contained in the online repository in the Standards and Procedures folder.

The GNEST CCB utilizes GSFC's web-based Centralized Configuration Management System (CCMS) to manage and track documents. Documents are baselined in the CCB by submitting a Configuration Change Request (CCR) in the CCMS. CCB members receive automatic notification via email, review the CCR and approve or disapprove the CCR, and enter comments regarding disposition of the CCR. The documents are loaded into the system and are linked from the CCR. Changes to baselined documents are handled in the same manner, in which a CCR is submitted along with the changes, reviewed and dispositioned by the CCB, and then baselined. The Ground Segment Manager is a member of the GNEST CCB and is responsible for ensuring that all CCRs are reviewed and assessed for any impact to the ground systems or mission operations.

Items controlled at the MOC level are maintained in the online repository. Discrepancy Reports (DRs) are used to report and track all discrepancies of MOC software and data under configuration control. DRs are managed and tracked in the VMOC/SERS system, which provides web access. The DR process is defined in the Standards and Procedures folder in the online repository.

7.7 ANOMALY RESOLUTION

Out-of-limit conditions detected in Swift telemetry or other ground segment operations generate alarms for the FOT and SOT, as appropriate. During off-shift hours, on-call personnel are paged and review remote displays to determine if operator intervention is required. If warranted, personnel will travel to the MOC to resolve the condition or further analyze the anomaly. Sustaining engineering personnel will be contacted as appropriate. Remote engineering stations aid in the speedy analysis and resolution of any anomalies. During normal operations (post-L&EO checkout), the chain of responsibility for different levels of anomalies begins with the FOT for routine out-of-limits. If a spacecraft emergency is declared, the Swift PI is notified and assumes responsibility.

The Swift observatory has significant auto-safemode capabilities. The spacecraft automatically places itself and its instrument complement in safehold mode should critical telemetry violations occur. In addition, each instrument will safemode itself should certain conditions occur. Safemode cannot be exited except by ground command. Standard procedures for resolution of anomalies and exit from safemode will be developed to address all known major failure modes.
The SERS operational anomaly tracking system is used to track the status of all spacecraft, instrument and ground segment anomalies for the duration of the Swift mission. The Swift Operations Manager and PSU Operations Lead approve closeout of all anomaly reports. The SERS system also contains pre-launch anomaly reports generated during Observatory I&T which continue to be maintained for reference in on-orbit operations.

7.8 MISSION STATUS REPORTING

The MOC participates in the regular MOWG status meetings, chaired by the MOC Director. Status is provided on all operations activities, ground system elements, and issues are discussed to develop a plan of action. The Omitron FOT Lead also provides a weekly status report to the PSU MOC Director to highlight the operations activities for the past week, and a monthly status report to PSU highlighting significant accomplishments, plans for the next month, status of open issues/concerns, and identification of any risk items. The FOT has regular discussions with the PSU Ops Lead for status and issue coordination. The FOT Lead maintains an action item list to track actions to closure, including assignee, due date, status, and comments for status/resolution.

8.0 STAFFING PLAN

8.1 LAUNCH AND 30-DAY CHECKOUT

The Swift MOC will be staffed by the FOT 24 hours a day, 7 days a week beginning at L-12 hours through the critical period of the 30-Day Checkout, nominally 2 weeks. The 24x7 coverage will be divided into two 12-hour shifts. At approximately L+15 days, pending completion of critical checkout activities and stable automated operations, the staffing will be reduced to a single shift, 12 hours a day, 7 days a week. An On-call Operations Engineer will be assigned for the unstaffed periods. At approximately L+22 days, the single shift will be reduced to 8 hours a day, 7 days a week. Staffing for support of critical activities following the reduction to a single shift will be scheduled on an as-needed basis. Table 8-1 provides the staffing plan for the 1st 30 days of the mission.

The following Omitron and PSU personnel will be certified as MOC operators and used to cover 2 shifts per day:

- Flight Operations Lead
- 3 Operations Engineers
- Ground Systems Engineer
- MOC Software Developers

In addition, the following personnel will provide operations support at the MOC:

- Spacecraft Team (Spectrum Astro)
- Instrument Teams (NFI - PSU, BAT - GSFC)
- Science Team (PSU)
- ITOS Development Team Support (GSFC) - TBD

Note that Spectrum Astro directs Swift operations until successful completion of the 30-Day Checkout, but the FOT will execute the plan as directed by the spacecraft team. The L&EO Director has authority and responsibility for all operations during this period.

Support elements will also be staffed during L&EO. The Malindi Ground Station will be staffed 24 hours a day for the duration of the mission. The FDF will be staffed 24 hours a day for the 1st week of the mission. The NCC will be staffed 24 hours a day, 7 days a week.

Table 8-1. MOC Staffing Plan for L&EO/30-Day Checkout

	DAY 1*	DAY 2*	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Prime Shift	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng Omitron software eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng Omitron software eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	- SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng
2nd Shift	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D

	DAY 8	DAY 9*	DAY 10	DAY 11	DAY 12	DAY 13	DAY 14
Prime Shift	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (8) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng
2nd Shift	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D	SA s/c engineer Omitron operator C Omitron operator D

	DAY 15	DAY 16	DAY 17	DAY 18	DAY 19	DAY 20	DAY 21
Prime Shift	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng B	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (4) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng
2nd Shift	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE

	DAY 22	DAY 23	DAY 24	DAY 25	DAY 26	DAY 27	DAY 28
Prime Shift	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron operator B Omitron gnd sys eng
2nd Shift	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE	On-Call OE

	DAY 29	DAY 30
Prime Shift	SA &EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator C Omitron gnd sys eng	SA L&EO Director SA s/c engineers (TBD) Instrument engineers (TBD) Omitron Ops Lead Omitron operator A Omitron gnd sys eng
2nd Shift	On-Call OE	On-Call OE

Note: "Critical" operations days are denoted with an asterisk. Critical days have been determined based on Spectrum Astro's checkout timeline, and include the first 48 hours of the mission.

RULES USED TO GENERATE THIS SHIFT SCHEDULE:

- Everyone gets a minimum of 1 day off every 7 days
- A minimum of 2 certified Operations Engineers will be available during the prime shift for the duration of the 30-Day Checkout
    - Operations Engineers A/B/C, Ground Systems Engineer, and MOC Systems Software personnel will be certified as Swift operators
- Flight Ops Lead and 2 Omitron Operators are preferred for the Prime Shift during critical activities
- Operations Engineer (vs. ground system engineer or software personnel) preferred for 2nd Shift
- Personnel get a day off between shift changes

8.2 VERIFICATION/INSTRUMENT CHECKOUT

The transition to normal operations phase staffing will begin at the end of the 30-day checkout and continue until stable automated operations is achieved. Upon successful completion of the checkout activities, the FOT will exercise the MOC automation capabilities and demonstrate sustained automated operations over a weekend. The FOT will be present in the MOC to monitor the automated operations and intervene if necessary. Pending successful execution of automated operations over a weekend, the staffing will be reduced to a single shift of 8 hours a day, 5 days a week, the nominal staffing for the normal operations phase of the mission. Staffing for support of critical or special activities following the reduction to a single shift will be scheduled on an as-needed basis.

The following Omitron and PSU personnel will provide 8 hours, 5 days a week staffing of the MOC, at the beginning of this period:

- Flight Operations Lead
- 3 Operations Engineers
- Ground Systems Engineer
- Student Operators

GSFC and PSU Instrument personnel and Spectrum Astro spacecraft bus personnel will be on-call 24 hours a day, and MOC software vendors will be available via phone support during the normal workweek.

The Malindi Ground Station will be staffed for all pre-scheduled passes for the duration of the mission, and personnel will be on-call 24 hours a day to provide help in case of a spacecraft emergency.

The full transition is expected to be completed by L + 2 months. Note that a "duty operator" will be on-call for automated MOC paging 24-hours a day to respond to ground system or observatory critical anomalies.

8.3 NORMAL OPERATIONS

The FOT staffing level is reduced as student operators are certified and begin to assume operational responsibilities in the MOC. Note that there will always be at least one certified operations engineer supervising activities in the MOC. There will be at least 3 personnel certified as Swift operators available at all times in case of sickness, vacation, attrition, or unexpected MOC support demands. Two half-time student operators will be trained and certified to assist with MOC operations.

In addition to the FOT and student operators mentioned above, MOC software and system administration support will be on-call 24 hours a day, as will spacecraft bus personnel from Spectrum Astro and instrument sustaining engineering personnel at PSU and GSFC.

MOC software vendors will be available via phone support during the normal workweek for the duration of the mission. Note also that sustaining engineering contracts will be maintained for all mission critical software for the duration of the mission.

APPENDIX A – ACRONYM LIST

APID	Application Process ID
ASCII	American Standard Code for Information Interchange
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ASINet	ASI Network
ATS	Absolute Time Sequence
BAT	Burst Alert Telescope
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
COP-1	Command Operation Procedure
COTS	Commercial-Off-The-Shelf
CP_PDU	CCSDS Path Protocol Data Unit
CRC	Cyclic Redundancy Check
DAS	Demand Access Service
DB	Database
DFCD	Database Format Control Document
DPU	Data Processing Unit
DTAS	Data Trending and Analysis System
ELV	Expendable Launch Vehicle
FDF	Flight Dynamics Facility
FoM	Figure of Merit
FOT	Flight Operations Team
FOV	Field-Of-View
FSW	Flight Software
GCN	Gamma-Ray Coordinates Network
GN	Ground Network
GNEST	Ground Network for Swift
GOTS	Government-Off-The -Shelf
GRB	Gamma-Ray Burst
GSFC	Goddard Space Flight Center
HEASARC	High Energy Astrophysics Science Archive Research Center
I&T	Integration and Test
ICD	Interface Control Document
ICU	Instrument Control Unit
ID	Identification
IRD	Interface Requirements Document
ISAC	Italian Swift Archive Center
ITOS	Integrated Test and Operations System
KSC	Kennedy Space Center
LANL	Los Alamos National Laboratory
L0	Level zero
LSB	Least Significant Bit
Mbps	Million bits per second
MOC	Mission Operations Center
MOT	Mission Operations Team
MOWG	Mission Operations Working Group
MPS	Mission Planning System
MRD	Mission Requirements Document
MRT	Mission Readiness Test
MSB	Most Significant Bit
NASA	National Aeronautics and Space Administration
NCC	Network Control Center

NFI	Narrow Field Instrument
NISN	NASA Integrated Services Network
NMC	Network Management Center (USN)
NORAD	North American Aerospace Defense Command
OAB	Brera Astronomical Observatory
OMI	Omitron
OOL0	Observation-Oriented Level 0
PA	Pennsylvania
PAPA	Predict Ahead Planner Algorithm
PDU	Packet Data Unit
PI	Principal Investigator
POL0	Pass-Oriented Level 0
PPT	Preplanned Target
PPST	Preplanned Science Timeline
PSU	The Pennsylvania State University
RS	Reed-Solomon
SCID	Spacecraft Identifier
SDC	Swift Data Center
SERS	Spacecraft Emergency Response System
sftp	secure file transfer protocol
SN	Space Network
SOH	state-of-health
SOT	Science Operations Team
SRD	Science Requirements Document
SSC	Swift Science Center
SSR	Solid State Recorder
STK	Satellite Tool Kit
STOL	Spacecraft Test & Operations Language
SwRI	Southwest Research Institute
TAKO	Timeline Assembler, Keyword Oriented
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
TLE	Two Line Elements
ToO	Target of Opportunity
UKSSDC	United Kingdom Swift Science Data Center
USN	Universal Space Network
UVOT	Ultra-Violet Optical Telescope
VC	Virtual Channel
VCID	Virtual Channel ID
WSC	White Sands Complex
WWW	World Wide Web
XRT	X-Ray Telescope